Spatial and Regional Issues in Vehicle and Fuel Modeling Analyses: HyTrans and TAFV Examples

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Overview of Presentation

- **Description of our Vehicle and Fuel Transition project**
- **Spatial/Regionalization issues we know we will address**
- **Ideas on broader opportunities for gains through regionalization and use of GIS**
- **(Do not survey wider realm of all regional transportation analysis)**

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Hydrogen Transition (HyTrans) Project Objectives & Accomplishments
(Sponsored in FY 2004 by PBA)

- √ **Rapidly create an integrated model of the transition to hydrogen *transportation* fuel**
- √ **Extend methods developed for the Transition Alternative Fuels and Vehicles (TAFV) Model**
- √ **Test HyTrans v1.0 and produce initial scenarios of market evolution.**
- • **Extend to greater detail, regionalization**
- • **Analyze scenarios & policies, cost-benefit**

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The "Chicken or Egg" problem is key to energy *transitions*, but economic models generally do not address the real barriers that create it.

- **Limited fuel availability depresses vehicle demand, limit fuel demand depresses fuel availability**
- **Vehicle and fuel infrastructure investments large, and not explicitly coordinated**
- **Scale economies:**
  - **costs high at low production**
- **Limited vehicle model diversity**
  - **Availability on only a few makes/models limits demand**
- **Learning-by-doing**
- **Slow capital stock turnover**
- **HyTrans represents all these interdependent barriers.**

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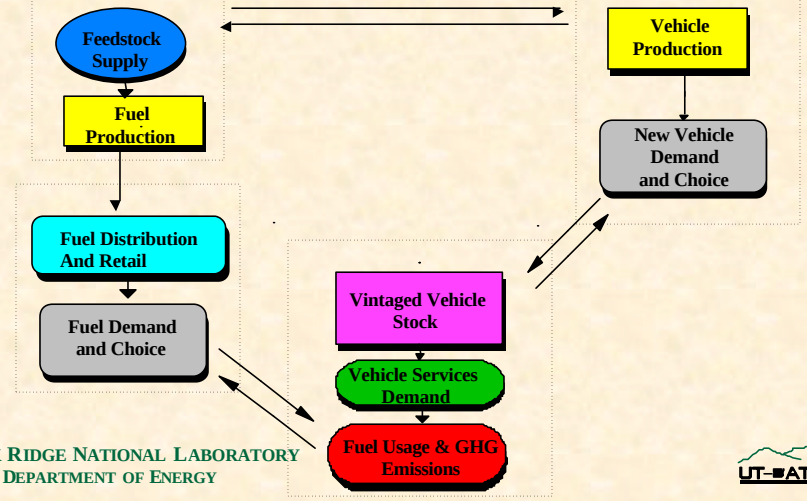
HyTrans finds a simultaneous market solution that integrates consumer, fuel producer, fuel distributor and vehicle manufacturer decisions.



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Key, interdependent market variables are solved endogenously with optimization, perfect or limited foresight.

- **Consumer choice**
  - Vehicle cost
  - Make/Model diversity
  - Fuel availability
- **Fuel availability** (% stations offering H in region)
  - Volume of fuel demand in region
  - Density of fuel demand
- **Fuel supply and cost**
  - Production and delivery processes
  - Scale of production
  - Density of demand
- **Manufacture of vehicles and cost**
  - Consumer demand
  - Scale economies
  - Learning-by-doing
  - Technological advancement

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HyTrans has an ambitious timeline.

9/03 – 5/04	6/04 – 9/04	10/04 – 9/05
HyTrans v. 1	HyTrans v. 2	Future Development

- **Version 1.0**
  - **Convert TAFV model**
  - **Develop mathematical representations of hydrogen production, delivery, demand**
- **Version 2.0**
  - **Represent 9 Census Regions**
  - **Add production/delivery technologies**
- **Future 3.0**
  - **Analysis of transitions, policies and measures**
  - **Simplified stationary demands**
  - **Added production and delivery technologies**
  - **Interaction with energy markets & economy**

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Spatial/Regionalization Issues Identified and Being Addressed

- **Feedstock/fuel supplies and costs at (large) regional level**
- **Spatial aspects of pipeline configurations**
- **Density-of-Demand variations by region**
  - **production scale and tech choice, and**
  - **delivery mode choice**
- **Plant to market distances and delivery cost**
- **Value of retail station availability to (mobile) consumers**
  - **on rural and interstate markets**
  - ***between* urban, less-urban & rural/interstate mkts**

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Introducing regional supply variability.

- **Cost of hydrogen production feedstocks**
  - **Biomass**
  - **Other renewables and electricity**
  - **Electricity generation synergy will have to wait**
- **Scale and costs will depend on demand**
- **Costs of hydrogen transportation and storage**
  - **Pipeline capital costs**
  - **Storage costs**

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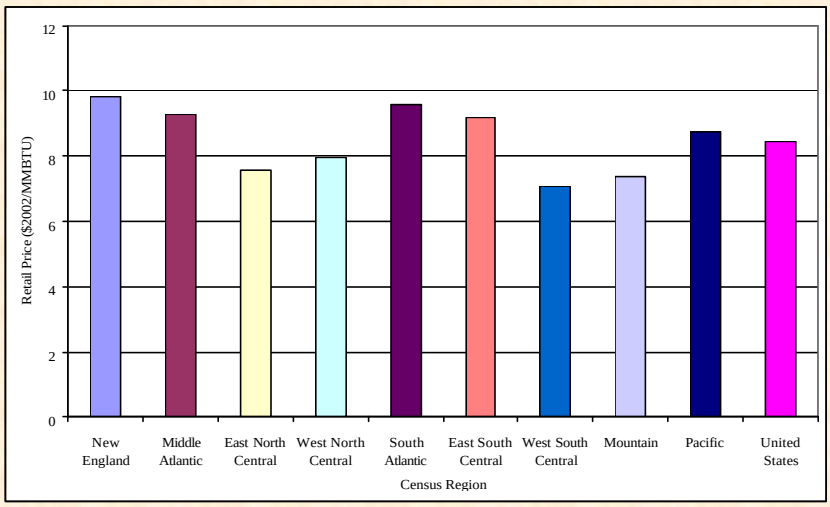
Feedstock Cost Regional Variations (e.g. Commercial Nat. Gas Price, 2001)



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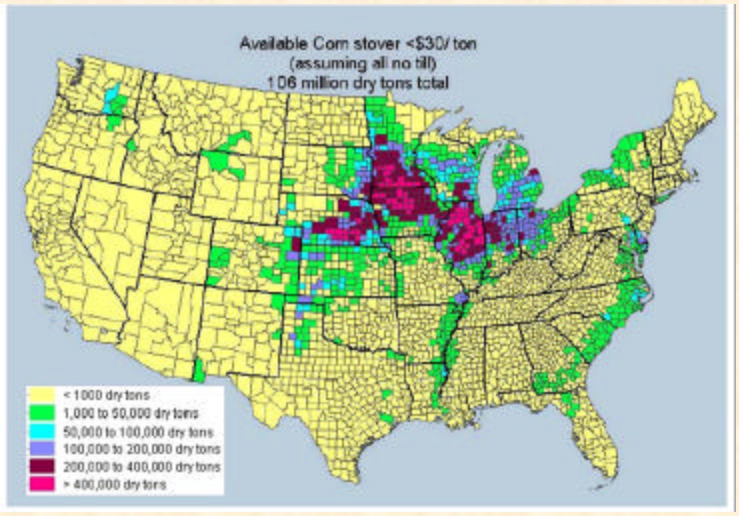
Supply curves that vary by region will be constructed for hydrogen feedstocks.



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Source: Graham R., et al, "Agricultural Residue Analysis", ORNL, forthcoming.

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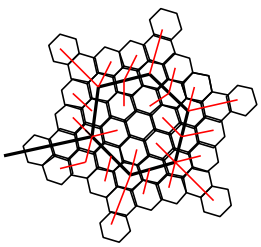
Spatial Aspects of Pipeline Configuration:
Better understanding of the likely structure, evolution and costs of regional pipeline systems, is needed.

Hypothetical Metropolitan H2 Pipeline Distribution System

43 forecourts with actual capacity of 2100 kg/day
a plant with actual capacity of 90,000 kg/day
Density of hydrogen demand is 10,000 kg/sq km/yr
Capital investment is about $100,316,800



Black line - trunk pipeline P1, 10''diameter
Red line - service pipeline P2, 3" diameter

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Account for Density-of-Demand variations by region

- **Drives production scale and tech choice, and**
- **Drives delivery mode choice**

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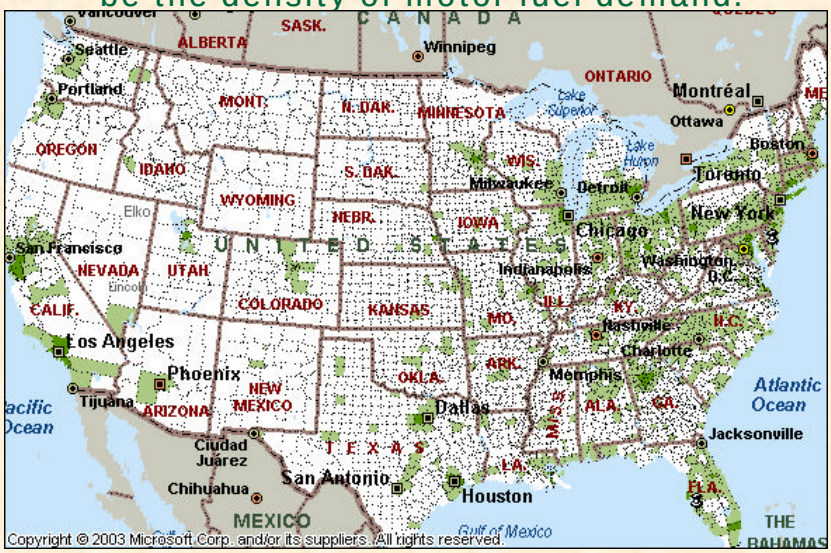
A key factor in infrastructure evolution will be the density of motor fuel demand.



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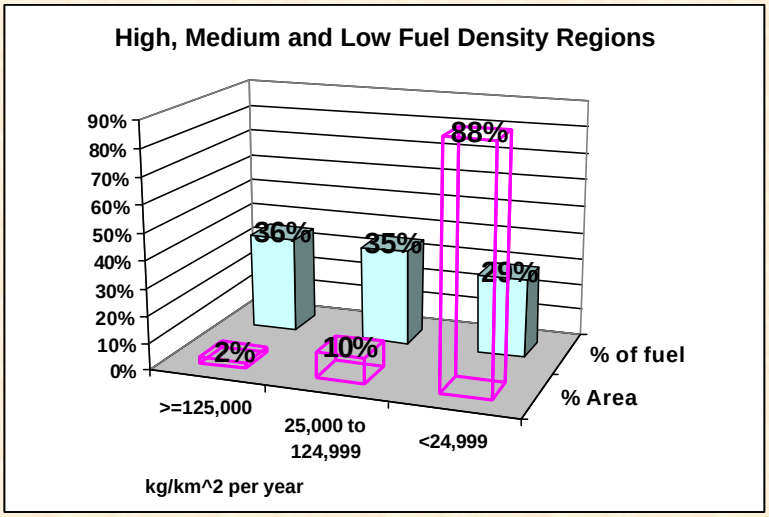
Most light-duty vehicle fuel is consumed in counties comprising about 10% of the land area of the US.



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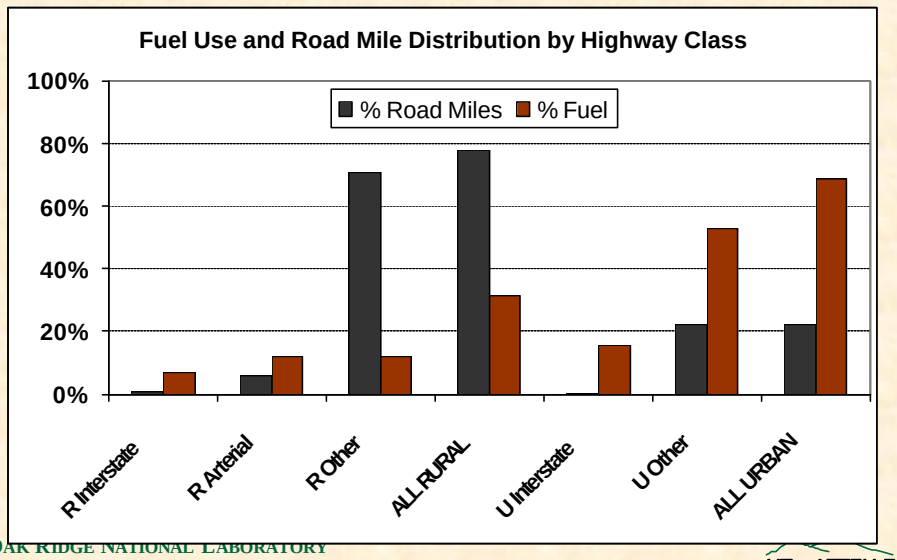
Thinking of highways as linear markets, most ***rural*** fuel is consumed on interstates and principal arterials.



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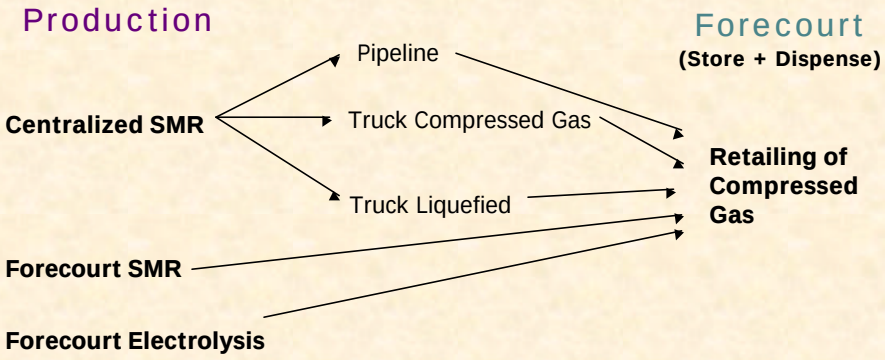
Delivery Mode Choice Will Depend on Distances, Demand Density, and Demand Volume

Delivery

Includes: Compression / Liquefaction + Storage + Dispensing + Transporting + Storage + Compression / Vaporization



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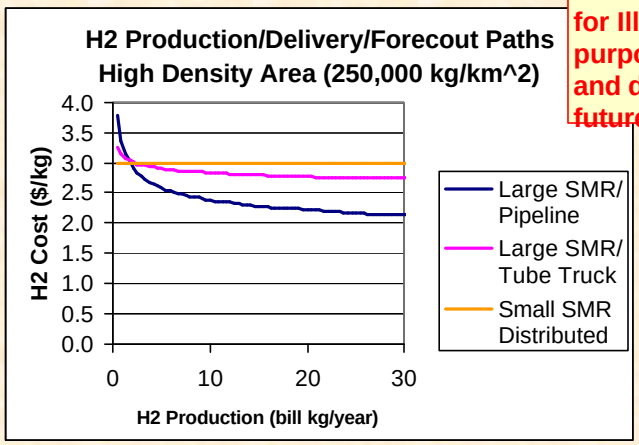
HyTrans Selects Among Production/ Delivery Pathways Based on Scale Economies and Distance/Density.

Results shown are for Illustrative purposes only and do not reflect future technology.



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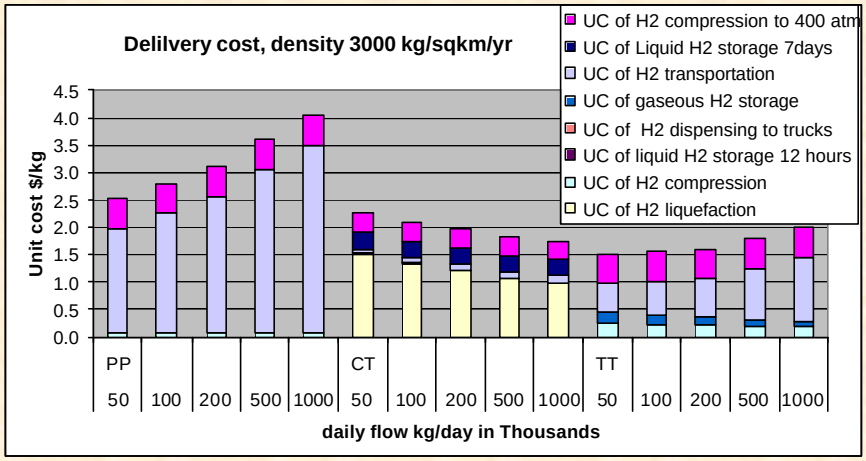
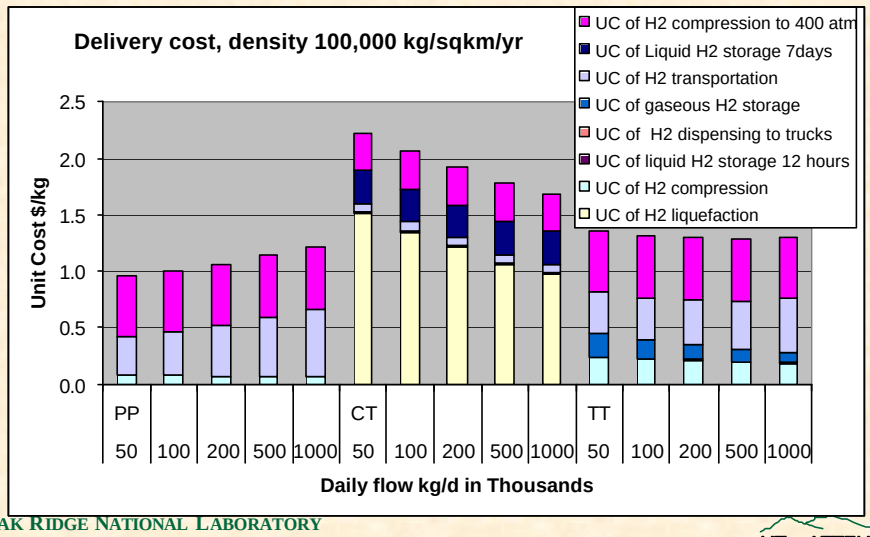
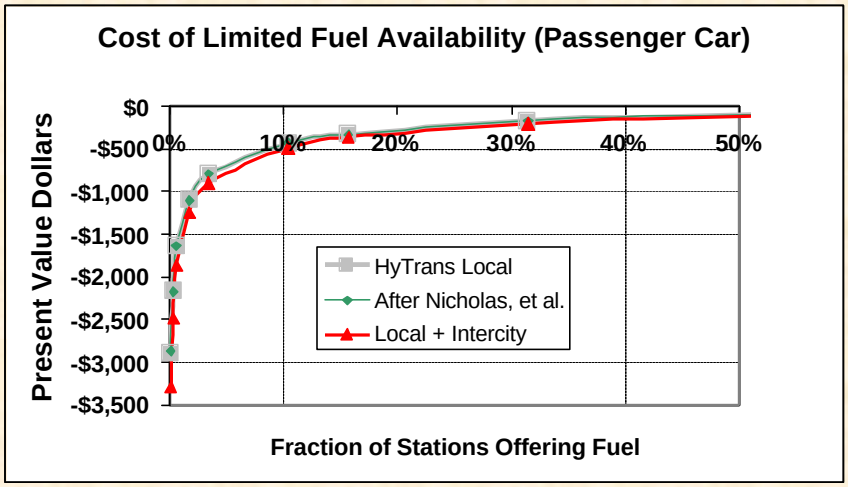
Delivery costs depend on both production ***scale*** and ***density*** of demand.



At high densities, pipelines do appear to dominate, but many questions remain.



Important Spatial Issue: Limited retail fuel availability is a major cost to consumers.



Improving our representation of fuel availability value to vehicle owner

- **UC Davis is doing a good job of measuring increased trip distance and travel time for limited local availability.**
- **The value of availability in non-local markets and other regions needs a rigorous logical framework.**
- **Availability in linear markets needs a rigorous formulation. Mark Melaina (U. Mich) addressing.**

Urban Area/Interstate Network Model

Trip and Interstate Segment Values Use to Estimate Station Siting Value

- **Some trips are more valuable than others**
- **Three components to determining trip value:**
  - **Cost of distance (fuel)**
  - **Cost of time**
  - **Destination value**
- **Cost of fuel and time are linearly proportional to distance**
- **Destination value is determined by gravity model**
  - **More people seem to want to drive from L.A. to Las Vegas than from L.A. to Kingman, AZ – though the distances are similar.**
- **Value of lining a particular interstate segment with (continuous) hydrogen stations will be proportional to sum of these three components**
- **Interstate segments will then be ranked according to these relative values**
- **Calibrate gravity model to 1995 American Travel Survey data for long distance trips between urban areas**

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Other, More Detailed Regional Issues in Vehicle Transition Modeling

- **Regional variation in H2 production cost**
  - **regional sequestration opportunities.**
- **Regional variation in fuel distribution**
  - **variations in existing delivery infrastructure (e.g. pipeline networks)**
  - **modeling evolution of pipeline infrastructure**
  - **modeling station siting**
- **Regional variations in demand**
  - **variations in consumer choice (e.g. suitability of vehicle or fuel types to niche/local conditions)**
  - **variations in temporal patterns of demand**